START 3

Superfund Technical Assessment and Response Team 3 – Region 8

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Technical Memo - Final
Removal Site Assessment for Mogul and Grand Mogul Mine Dumps

Mogul and Grand Mogul Mine Site
Silverton, San Juan County, Colorado

TDD No. 1005-04

March 21, 2012

URS
OPERATING SERVICES, INC.

In association with:
Garry Struthers Associates, Inc.
LT Environmental, Inc.
TechLaw, Inc.
Tetra Tech EMI
TN & Associates, Inc.

TECHNICAL MEMO – FINAL
Removal Site Assessment for Mogul and Grand Mogul Mine Dumps

MOGUL AND GRAND MOGUL MINES
Silverton, San Juan County, Colorado

EPA Contract No. EP-W-05-050
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TECHNICAL MEMO – FINAL
Removal Site Assessment for Mogul and Grand Mogul Mine Dumps

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1.0 INTRODUCTION

URS Operating Services, Inc. (UOS) Superfund Technical Assessment and Response Team 3 (START) has been tasked by the U.S. Environmental Protection Agency (EPA), Region 8, under Technical Direction Document (TDD) # 1005-04, to conduct field activities at the Mogul and Grand Mogul Mines (CERCLIS ID No. CON000802803) in Silverton, San Juan County, Colorado. Fieldwork for this Technical Memo was performed in June and July 2010.

This Technical Memo provides a summary of information collected during the site activities. It has been prepared in accordance with TDD No.1005-04. Activities were performed in accordance with the "UOS Generic Quality Assurance Project Plan" (QAPP) (UOS 2005).

2.0 SITE ACTIVITIES

- Site visits to the Mogul and Grand Mogul mines were conducted during June 14 - 16 and July 21 - 22, 2010 (Figure 1). The purpose of the site visit was to gather information needed to evaluate ongoing releases of mine water and acid rock drainage and to assess potential options to mitigate those releases. The primary focus of these investigations was to assess the waste rock dumps in terms of contribution to the releases to Cement Creek. Laboratory analysis was performed by the TestAmerica Laboratory in Arvada, Colorado. Photo documentation is provided in Appendix A. Site tasks included:

- Record physical and chemical parameters of surface water flows and collect surface water samples near the Mogul and Grand Mogul Mine waste piles to assess surface water and waste pile interactions.

- Characterize waste rock piles identified by the Bureau of Land Management (BLM) and the U.S. Geological Survey (USGS), and estimate waste pile volumes and surface areas.

- Performing test pit investigations to assess potential adit drainage, infiltration, and groundwater flows into and out of the Mogul and Grand Mogul waste piles.

- Perform GIS data gathering and ground-truthing to field-verify a potential repository sighting analysis.

3.0 BACKGROUND

Four main waste piles and associated surface water drainage were assessed during the site visits. One pile is located at the Mogul Mine site, and three piles are located at the Grand Mogul Mine site (Figure 2).

3.1 MOGUL MINE

The Mogul Mine area is located approximately 11,370 feet above mean sea level (AMSL) and consists of a waste rock pile and an open adit. The Mogul Mine resides in a small glacial depression adjacent to Cement Creek bounded by talus, solifluction deposits, and bedrock outcrops. Cement Creek flows to the north of this depression (Figure 2). Shallow soils have developed within the basin. To the west, or down gradient of the Mogul Mine, a relatively flat saturated area receives surface and shallow groundwater from seeps and springs. Surface water is channeled along the northeast side of the saturated area, and this channel drains to Cement Creek. An access road passes through the Mogul Mine site area. Though narrow, it is suitable for high clearance vehicles and track-mounted excavation equipment.

The Mogul Mine adit is open and flows approximately 0.138 cubic feet per second (cfs) (62 gallons per minute [gpm]) as measured by EPA in June of 2010. A Parshall flume has been installed to monitor adit effluent which is channeled to the south of the main waste rock pile. A small corrugated metal shed is present on top of the Mogul Mine waste rock pile near the adit. Some scattered mine-related debris including wood material exists at the site; however no significant cultural debris appears to be present.

3.2 GRAND MOGUL MINE

The Grand Mogul Mine site is up-valley and east of the Mogul Mine site at approximately 11,680 feet AMSL. Access to the Grand Mogul Mine is via a four wheel drive road that bisects the Mogul Mine site and, more indirectly, via an access road that traverses the north wall of the basin above the mine (Figure 2). At the time of the site visit in June, a large snowfield covered the eastern portion of the basin. Shallow soils and alpine tundra typify the Grand Mogul basin. Basin walls are bounded by steep talus, bedrock outcrops, and solifluction deposits. The Grand Mogul Mine includes three waste rock piles (numbered piles 1, 2, and 3, Figure 3) that are spaced throughout the upper Cement Creek basin.

There does not appear to be an adit associated with Pile 1; its morphology and location suggest that this pile may have been transported from other mine workings to its current location. A grate-covered underhand stope is exposed approximately 60 feet to the north of Pile 2. Small amounts of cultural debris are scattered throughout the basin; however, no significant mine workings aside from the stope at Pile 2 are evident.

4.0 WASTE ROCK PILES

4.1 MOGUL MINE PILE

The Mogul Mine site area includes one large waste rock pile (Figure 3, Photo 1). The waste rock pile is bisected by a four-wheel-drive access road into two tiers (Figure 2). The upper tier (Tier 1) consists of multiple lobes of primarily sulfide-bearing and vein-derived quartz waste rock. The tier appears to have supported narrow-gauge ore rails although no cultural debris or rail debris was observed on the waste rock pile. The maximum thickness of Tier 1 is estimated at 30 feet, based upon field observation. Grain sizes within the tier range from silty to coarse-grained sand including cobbles and boulders up to approximately 20 inches in diameter. Surface water flow at the base of Tier 1 was visually estimated at 0.02 cfs (10 gpm) at the time of the June site visit. Adit water from the Mogul Mine has been directed around the south side of the waste rock pile in order to sequester flow and prevent infiltration into the main rock pile. The adit discharge is contained in a rubberized plastic channel for approximately half of the distance downslope of the waste rock pile. From there it joins other basin discharge, is channeled, and enters Cement Creek.

The lower tier (Tier 2) of the Mogul Mine waste rock pile consists primarily of sulfide-bearing and vein-derived quartz rock. Several outcrops of bedrock were observed in the lower tier, which suggests that the overall thickness of the lower tier may be shallow relative to the upper tier (Photo 5). A small spring was observed issuing from the base of Tier 2, visually estimated at 2 to 3 gpm.

An approximately 100-foot-long trench was excavated for geologic observation along the northeastern boundary of Tier 1 on July 22 (Figure 2). The westward-to-eastward transecting trench was excavated to a depth of 9 feet below ground surface (bgs) where bedrock was encountered. The eastern extent of the excavation was located near the adit portal. A horizontal distance of 20 feet was maintained between the trench and the portal to minimize potential impacts to the portal. Excavated materials were returned to the trench following geological logging, and the excavator was used to compact the material during replacement. Photo 19 shows the excavated area following material replacement.

Water was observed entering the trench in the eastern corner closest to the portal. The rate of inflow was visually estimated at 2 gallons per minute. The water pooled in the base of the excavation. Photo 18 shows the excavation profile where the spring was observed. Two waste rock samples, MMWR01 and MMWR02, were obtained from excavated material derived from the western and eastern ends of the trench, respectively. Samples were submitted for geotechnical and chemical analysis; results are presented in Table 2.

As part of the investigation for a potential repository location two test pits, Test Pit 1 and Test Pit 2 (Figure 2), were also excavated in an area adjacent to the mine dump. The depth of the test pits was limited by the presence of shallow bedrock with Test Pit 1 excavated to a depth of 7 feet bgs, and Test Pit 2 was excavated to 5 feet bgs. Water was not observed in either pit. Sample MMTP01was obtained from Test Pit 1 for geotechnical and chemical analysis. No sample was collected from Test Pit 2 as the observed lithology was similar to that of Test Pit 1. Mine workings were not disturbed during these excavations and care was taken to restore conditions to those existing prior to excavation. Photos 20 through 23 show Test Pit details.

4.2 GRAND MOGUL MINE PILES

The Grand Mogul Mine area contains three main waste rock piles; Pile 1, Pile 2, and Pile 3 (Table A, Figure 4). The piles are located along a west to east transect up-basin with pile 2 located approximately 500 feet beyond pile 1, and pile 3 approximately 250 feet beyond pile 2.

4.2.1 Waste Rock Pile 1

Waste Rock Pile 1 is the smallest of the three piles at Grand Mogul and consists of a single pile with a visually estimated maximum thickness of 15 feet (Table A, Photo 12). Waste Rock Pile 1 is also referred to in BLM reporting as the “Lower Waste Pile” (BLM 2006). This pile is flat-lying and is contained within a small tributary channel of Cement Creek. Materials encountered in this pile consisted of mineralized waste bedrock and sulfide-bearing and vein-derived quartz. A small spring emanated from the down gradient base of this pile and had an estimated discharge of approximately 1 gpm on June 16 in a westward direction. Grain sizes of waste rock within the rock pile consist of silty to coarse sand and waste rock cobbles up to approximately 12 inches in diameter.

4.2.2 Waste Rock Pile 2

Grand Mogul waste rock Pile 2 is referred to as the “Grand Mogul Stope Complex” by the BLM (BLM 2006) (Table A, Photos 10, 11, and 15). It consists of two large lobes of mineralized waste rock that lie beneath the four-wheel drive access road (Figure 4). Immediately to the north of the waste rock piles is an underhand mine stope that is covered with a large safety grate. The maximum thickness of the two main waste rock pile lobes is estimated at 25 feet. Grain sizes of waste rock within the two lobes consist of silty to coarse sand and waste rock cobbles up to approximately 12 inches in diameter.

Surface water was observed flowing from Pile 3, and past the toe of Pile 2 (Figure 4). Additional input from a seep within Pile 2 may contribute to this flow but it was not discernable during field observation. Surface water flow near the base of Pile 2 was visually estimated on June 16 at approximately 20 gpm to the south and west.

A third test pit, Test Pit 3, was excavated to 4 feet bgs east of the Grand Mogul Mine Waste Rock Pile 2 to determine the depth of cover in the area adjacent to the pile (Figure 4). No water was observed in this pit. Soil materials sample MMTP02 was obtained from this pit for geotechnical and chemical analysis. Care was taken to restore site conditions to those prior to excavation.

4.2.3 Waste Rock Pile 3

Waste rock Pile 3 is the largest of the Grand Mogul Mine piles (Table A) and, at the time of the site visit, its northwestern and northeastern flanks were partially covered with snow. The pile consists of a large multi-lobe pile and a smaller eastern lobe (Figure 4) (Photos 9, 13, and 16). The waste rock pile is typified by mineralized bedrock cobbles with grain sizes ranging between fine sand and pea-gravel-sized waste rock. Large cobbles of waste rock are also present within, and on top of the pile. A spring flowing to the south and west at an estimated rate of 12 gpm on June 16 was observed issuing from the toe of Pile 3.

A second trench (Trench 2, Figure 4) was excavated on July 22 into the northeastern extent of the pile in an attempt to discern the location of a possible collapsed adit portal and assess the presence of other seeps entering the waste pile along this edge (Photo 27). The east-to-west transecting trench was excavated in two phases, the first extending 25 feet to the southwest of the suspected location of the mine adit, to a depth of 15 feet. Bedrock was encountered at the bottom of the excavation along its entire length. Waste rock and natural talus were encountered along the trench with waste rock being prevalent in the eastern 15 feet, and then natural rock being encountered along the remaining 10 feet. The trench walls began to fail when talus was encountered and, at this point the excavation was terminated. A seep was encountered on the northern wall of the excavation. The seep was observed at between 4 and 8 feet bgs and was approximately 4 feet in width. Discharge from the seep was visually estimated to be less than 1 gpm. Further investigation of this location was not undertaken due to the instability of the talus slope adjacent to the excavation.

The second phase of the trench was extended an additional 85 feet toward the west for a total trench distance of 110 feet. No seeps were encountered along this western extent; talus was encountered along the trench from 35 feet to 110 feet. Depth to bedrock was approximately 15 feet bgs at the east origin, reducing to approximately 8 feet bgs at the northwestern extent.

No mining structures were encountered or disturbed during the excavation. Excavated materials were replaced and compacted using the weight of the excavator.

5.0 VOLUME ESTIMATION

Volumes for the Mogul and Grand Mogul waste piles were estimated using data gathered during the site visits and were analyzed in a Geographic Information System (GIS). During the site visit, the salient lobes and thickest portions within each waste pile were identified, their central points were located with a Differential Global Positioning System (DGPS), and their thicknesses at their highest point were estimated. The boundary of the waste rock pile was also surveyed using a DGPS in order to provide area estimates and a base footprint for each waste pile. DGPS measurements were converted to a three dimensional (3D) surface, a convex hull in a GIS. GIS 3D spatial analyst was then used to summarize the interior volume of the convex hull, and to determine its 3D surface area. The two dimensional (2D) footprint was also calculated from DGPS data and was summarized in the same GIS. Waste rock volumes and areas are presented in Table A. BLM estimates obtained in 2006 are also included.

TABLE A
Volume Estimates – Waste Piles*

Mine	Pile Number	BLM* Name	3D Surface Area (ft^2)	Footprint Area (ft^2)	Volume (yds^3)	BLM* Volume (yds^3)
Mogul	1	--	106,068.5	101,590.6	41,374.7	--
Grand Mogul	1	Lower Waste Pile	8,449.7	4,187.2	845.0	--
Grand Mogul	2	Stope Complex	22,539.8	19,751.9	6,925.9	8,000
Grand Mogul	3	Eastern Waste Pile	42,754.6	39,041.0	18,750.2	9,000

* "Removal Preliminary Assessment Report, Grand Mogul Mine, Silverton, CO" BLM 2006
ft^2 – square feet
yds^3 – cubic yards

6.0 WATER PARAMETERS AND SAMPLE COLLECTION

During the site visit in June 2010, field water parameters were collected at various points upgradient and down gradient of all waste rock piles to determine any influence by the waste rock on surface water discharge. Field parameters gathered during the site visit are included on Figures 3 and 4 and summarized in Table B.

Three water samples were collected at the Mogul Mine site and analyzed for total and dissolved metals by the TestAmerica Laboratory in Arvada, Colorado, using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and atomic emission spectroscopy (AES) analyses (Table 1). Sample locations included a waste rock seep below the toe of the pile (sample MMSW01), Mogul Mine adit flow at the toe of the pile (sample MMSW02), and Mogul Mine adit flow from a mid-point location on the pile (sample MMSW03). These water samples are compared to water samples from the same watershed, also collected in June of 2010 during a separate sampling event (Table 1).

TABLE B
Field Parameters – June 2010

Location	pH	Conductivity (mS/m)	Temp °C	Est. Flow Rate (gpm)
MMSW01. Mogul mine waste rock Seep below toe of pile	3.82	56.9	12.90	10
MMSW02. Mogul mine adit flow at	4.01	82.0	10.50	3

TABLE B
Field Parameters – June 2010

Location	pH	Conductivity (mS/m)	Temp °C	Est. Flow Rate (gpm)
toe of waste pile				
MMSW03. Mogul mine adit flow at mid waste rock pile	4.50	81.4	10.40	10
Mogul Adit	4.61	96.9	7.50	62
Grand Mogul Pile 1 spring	4.78	15.7	10.20	1
Cement Creek Confluence	5.21	16.8	8.10	1,000
Surface Water near Grand Mogul Pile 2	3.86	16.6	11.30	20
Grand Mogul Pile 3 spring	3.92	14.6	8.90	12
Cement Creek Upgradient	5.38	11.5	8.40	1,000
Mogul Toe	2.67	--	--	3

gpm – gallons per minute mS/M = milliSiemens per meter *Parshall Flume Measurement, EPA June 2010
-- Not collected

7.0 WASTE ROCK SAMPLING

Mine dump waste rock samples were obtained in 1996, 1997, and 2010 at the Mogul and Grand Mogul mines (UOS 2009, USGS 2007). Specific sample locations on the waste rock piles are unknown. Table 2 includes metals concentrations and Synthetic Precipitation Leaching Procedure (SPLP) laboratory analysis from those sampling events. For ease of presentation the following discussion is based upon zinc observations. Other metals that are present on site share similar relationships.

SPLP samples in Table 2 provide a value that represents the potential leachable concentration from the material being analyzed. Total Metals laboratory results presented in Table 1 indicate a release of metals to surface water flows. For example; The SPLP concentration of zinc at the Grand Mogul Pile 3 is 10,000 micrograms per Liter (µg/L). During the June 2010 sampling event (Table 1), a Total Metal concentration of 3,350 µg/L of zinc was observed in a seep releasing from the Grand Mogul Pile 3 (sample CC01C). A water sample hydraulically upgradient of the Grand Mogul mine (sample CC01F, Table 1) revealed a zinc concentration of 379 µg/L, nearly 9 times less than the amount observed in the Grand Mogul pile 3 seep, and 26 times less than the observed SPLP leachable amount of 10,000 µg/L.

Uncertainties exist as to the provenance of the water at CC01C. The water flowing at this location may be from a collapsed mine adit that is flowing in the shallow subsurface, or it may be ground or other surface water that is interacting with Pile 3 itself.

Inductively Coupled Plasma - Atomic Emission Spectroscopy (ICP-AES) laboratory analysis (Table 2) indicates total amounts of metals within the material being analyzed. ICP-AES zinc values at the Grand Mogul Pile 3 ranged from 30,000 to 34,000 mg/kg. Mogul Mine values for zinc ranged from 5,800 to 279 mg/kg. Lead values ranged from a maximum of 24,400 mg/kg at the Mogul Mine to a minimum of 24,000 mg/kg at Grand Mogul Pile 3.

8.0 METALS LOADING

Comparisons between START and EPA data collected during June 2010 sampling events show that both the Grand Mogul and Mogul mines are impacting Cement Creek at specific sample locations (Tables 1, 2 and 3, Figures 3 and 4). However, the data set represents a “snapshot” in time and may not represent perennial conditions. For ease of presentation the following discussion is based upon zinc observations. Other metals that are present on site share similar relationships.

Table 3 includes selected samples and analytes (CC01F to CCOPP-12) which are presented in an order that represents an upgradient toward down gradient profile within the Cement Creek basin near the Mogul and Grand Mogul mines. In the table, the location type describes the location of the sample relative to Cement Creek. The term “Feature” refers to samples that were taken from surface water near or derived from mine features while “Cement Creek” refers to samples that were collected directly from Cement Creek. In the following discussion, “below” refers to a sample or feature that is located down gradient and downstream in its relation to other features, and “above” refers to a sample or feature that is located upgradient and upstream in its relation to other features. These data represent conditions observed in the Cement Creek watershed for June 2010.

For the purposes of this discussion, Cement Creek sample CC01F; upgradient of the Mogul and Grand Mogul mines was established as a background sample. The sample results from this location establish water quality conditions of Cement Creek prior to interaction with either Mogul or Grand Mogul mine-related features. Metals water loading calculations were determined by the equation [ppd = μg/L (cfs)(.00539)] where μg/L = micrograms of metals content per liter of water, cfs = water flow measured in cubic feet per second, while the constant 0.00539 was established to convert the results to pounds per day (ppd).

8.1 GRAND MOGUL MINE

The Grand Mogul Mine is upgradient of the Mogul Mine. The most upgradient features at the Grand Mogul Mine are Piles 3 and Pile 2 (Figure 4). Subtracting background sample CC01F from CC01H shows the relationship between Pile 3 and Pile 2. Data contained in Table 3 show that 24.5 pounds per day (lbs/day) of zinc enters Cement Creek between Sample locations CC01F and CC01H. Furthermore, the overall concentration of zinc in Cement Creek increases from 370 µg/L at CC01F to 1,120 µg/L at CC01H, which is approximately 400 feet below Grand Mogul Pile 2.

No waste rock seep was observed emanating from Pile 2 and, therefore, the primary source for the increase in zinc at CC01H is likely from Pile 3. It is possible that the discharge observed during trenching activities was issuing from a collapsed adit; this water interacts with the waste rock piles before discharging from the toe of Pile 3. The discharge rate observed in the trench was lower than that of the toe, indicating that other sources of water are entering the pile, or that there may be different flow paths within the waste pile material. Given the current dataset, it is not possible to determine how the water chemistry of the seep is affected by interactions with the waste rock pile.

Cement Creek combines with the unnamed tributary below Grand Mogul piles 2 and 3 (Figure 4). Sample CC01T documents the observed change in Cement Creek after its confluence with the unnamed tributary: flow rate increases by 2.68 cubic feet per second (cfs), overall zinc loading increases by 9 lbs/day, and overall zinc concentration decreases from 1,120 µg/L to 978 µg/L. These data suggest that while Cement Creek contributes a load increase of approximately 30 percent before its confluence with the unnamed tributary, it has an overall diluting effect on zinc concentrations on the unnamed tributary flow that enters it.

Sampling was not performed in Cement Creek immediately below Grand Mogul Pile 1 during these events. It is, therefore, not possible to determine the direct effect of Grand Mogul Pile 1 on the concentration or load in Cement Creek. However, its contribution to these factors is likely small due to low flow rates observed near the pile (0.016 gpm – average recorded during August and September of 2009), relatively low concentration value (1,290 µg/L), and low zinc load (estimated 0.11 lbs/day) relative to other mine features (Tables 1 and 3). Comparisons of zinc loading in Cement Creek between Mogul Mine features and Grand Mogul Pile 1 further indicate that Grand Mogul Pile 1 does not contribute significantly to the load and concentration of zinc in Cement Creek (Table 3).

In summary, the increase in zinc loading to Cement Creek from the Grand Mogul Mine piles 2 and 3 is 24.51 lbs/day and the concentration within Cement Creek increases 750 µg/L.

8.2 MOGUL MINE

Mogul Mine consists of an open and flowing mine adit and associated waste rock pile (Figure 3). Several ephemeral seeps and other flowing mine features exist along the southern flank of the valley (Figure 2).

The feature at the Mogul Mine with the largest recorded flow rate (0.138 cfs, or 62 gpm) during the June sampling event performed by START and the EPA is the mine adit itself (sample location CC02D). Mine adit water also contains the largest concentration of zinc observed in the Mogul Mine area (22,900 µg/L) and contributes the largest zinc load of all surface water features observed and sampled during the June sampling event (17.05 lbs/day).

The location of sample MTD-3 is below the observed mine adit flow. All seeps that appear to interact with the Mogul Mine waste rock pile appear to be channelized at this location, including the adit flow itself (CC02D). Therefore, MTD-3 is assumed to encapsulate surface water flows that either emanate from or interact with mine features. This sample location represents the surface water characteristics prior to drainage into Cement Creek. With an observed flow rate of 0.394 cfs (177 gpm) water flowing at MTD-3 contributes a zinc load of 17.41 lbs/day and a zinc concentration of 8,190 µg/L (Table 3).

Seeps issuing from the waste rock were observed and sampled at location MTD-1 and at MMSW01 (Table 3). Though these samples contain elevated loads and concentrations of zinc, they represent approximately 1 to 10 percent of the load observed at MTD-3. The concentration of zinc decreases between the mine adit and MTD-3, suggesting that the waste rock seeps at MTD-1 and MMSW01 contribute additional surface water, but limited amounts of zinc.

The overall surface water concentrations at MTD-3 suggest that seeps interacting with the waste rock do not exhibit a significant increase in metals concentrations, and other subsurface flows are diluting zinc within the adit flow, ultimately indicating that the waste rock pile contributes little concentration and load to the surface flow that enters Cement Creek. The mine adit flow itself appears to be the prime contributor of metals load from the Mogul Mine. Uncertainties exist in this interpretation as this data does not account for any water inputs to Cement Creek (surface or subsurface) that are not encapsulated by the channel at MTD-3.

8.3 CEMENT CREEK BELOW THE MOGUL AND GRAND MOGUL MINES

Conservative estimates of zinc loading to Cement Creek from the Grand Mogul mine were calculated based on stream flow measurements and zinc concentrations from sample locations CC01H (basin flow from piles 2 and 3), and CC02i (pile 1 drainage) which indicate that 24.62 lbs/day are loading into Cement Creek from the Grand Mogul mine area. This calculation excludes 9.2 lbs/day of measurable zinc load from upstream sample location CC01F. A zinc load from the Mogul mine of 17.41 lbs/day was estimated based on data from-location MTD-3 below the Mogul mine complex, prior to discharge into Cement Creek.

Therefore an estimated zinc load-of 42.03 lbs/day to Cement Creek can be attributed to the Grand Mogul and Mogul mines. This amount is equal to 44 percent of the total zinc load (96.61 lbs/day) measured in Cement Creek at sample location CCOPP-12 approximately 1 mile down gradient of the Mogul mine. It is likely that the total metals loading from the Grand Mogul and Mogul mines is not fully accounted for due to diffuse flow of contaminated groundwater into Cement Creek. The contaminated groundwater results from infiltration of rain and snow, with high dissolved metals resulting in the vicinity of the grand mogul and mogul mines as well as possible subsurface discharge of mine water to Cement Creek.

9.0 POTENTIAL REPOSITORY SIGHTING

Prior to the site visit, a preliminary basin model for potential repository delineation was created using existing published data sets from the Cement Creek watershed. During the site visit, an area that met suitable criteria for a repository was outlined and identified (Figure 5). This area is to the northwest of the Mogul Mine and is coincident with the preliminary basin model.

The repository area is 3.8 acres in size and has a slope of less than 20 percent. Existing roads already intersect the site. The repository is within 100 feet of most of the Mogul Mine waste pile. Shallow soils have developed in the repository site area and may provide favorable borrow source and/or capping material for repository engineering considerations. The repository is within 300 feet of Cement Creek;

however, it may be possible that not all of the repository area would be utilized for waste consolidation and disposal.

A preliminary GIS analysis that combines several datasets in a qualitative ranking system was performed. To complete the analysis, data are assigned a numeric value and then mathematically multiplied to the overall model. High values represent areas with most favorable characteristics. For example, in the repository model, areas closer than 300 horizontal feet to existing surface water are less favorable for a repository, as placing waste rock this close to water increases the risk of mine waste adversely affecting surface water. A dataset was created in which any area closer than 300 feet to known surface water is assigned a value of 1. Any area farther than 300 feet is assigned a value of 2. The value 1 is less favorable than the value of 2. In a like manner, other thematic data (detailed below) is assigned numeric values. After all datasets are assigned values, the areas are multiplied together. High values within the data represent areas of most favorable characteristics for the location of a waste repository.

This model combines the following criteria to isolate a portion of the Cement Creek watershed for favorable repository locations (USGS 2002, Gesch 2007, Gesch et al. 2002):

- Elevation – The National Elevation Dataset (NED) 10-meter Digital Elevation Model (DEM) was used to derive local elevations.
- Slope – Slopes greater than 20 percent were not considered.
- Roads – Areas close to existing mine roads were considered more favorable.
- Surface Water – Areas within 300 feet of existing surface water were considered less favorable.
- Geology – Bedrock geology was considered most favorable while talus and other geologically young rock units were less favorable.
- Structures – Areas within 300 feet of previously mapped faults and large geologic structures were considered less favorable.

10.0 OBSERVATIONS

The following summary is presented for both surface water and waste rock data collected from Mogul and Grand Mogul Mines. The conclusions are based upon conditions of surface water and mine waste observed at these mines in June 2010. These conclusions and observations do not consider seasonal variation.

- The Grand Mogul Mine contributes a significant increase of metals as compared to upstream sample concentrations. For example, zinc concentrations in Cement Creek increase from 370 ug/L above the mine to 1,070 ug/L below Piles 2 and 3 (the main waste rock dump). It is likely that the majority of this load comes from Grand Mogul Pile 3, which likely includes subsurface flows interacting with waste rock.

- Cement Creek enters the basin below Grand Mogul Piles 2 and 3, and at the time of this sampling, it was carrying a zinc load of 14.49 lbs/day and a concentration of 1,070 μg/L.

- It is unlikely that Grand Mogul Pile 2 contributes significant amounts of zinc to Cement Creek as no surface water was observed interacting with the pile and flowing into Cement Creek.

- Grand Mogul Pile 1 does not appear to contribute significant amounts of zinc to Cement Creek.

- Mogul Mine waste rock contributions to the metals load in Cement Creek appear to be small as indicated by concentrations and flow observed at surface water runoff features below the Mogul Mine sample location, e.g., sample MTD-3. As much as 95% of the load observed at MTD-3 may come from the Mogul Mine Adit discharge. Conditions during high flow run-off events may temporarily increase the relative load from the waste dump. Trenching performed in the top of waste dump showed that only a minor amount of subsurface seepage. It does not appear that the dump is contributing much metals loading.

- Combined, the Mogul and Grand Mogul mines contributed a significant portion of the overall zinc load to upper Cement Creek above location CCOPP-12 in June 2010.

- Additional tributaries enter Cement Creek between the Mogul and Grand Mogul mines and the downstream sampling point CCOPP-12, approximately 1 mile down stream. These tributaries and/or other sources were contributing 56 percent of the overall zinc load on Cement Creek at CCOPP-12.

11.0 LIST OF REFERENCES

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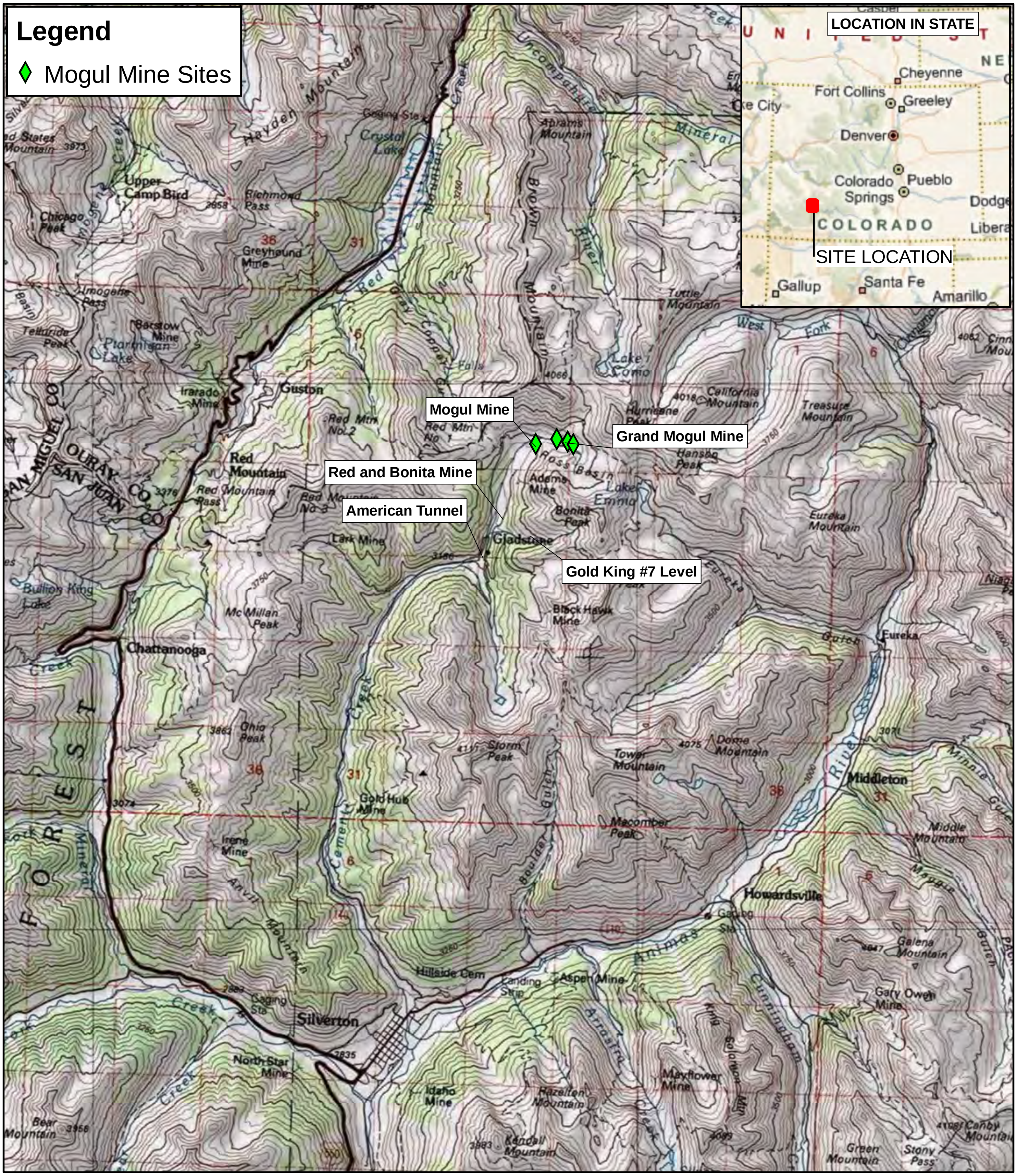

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Universal Transverse
Mercator Zone 13 North
North American Datum 1983

N

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Miles

1 inch | Page Size: 8.5 x 11

TDD Title: **MOGUL AND GRAND MOGUL MINES**

Figure: 1

Figure Title: SITE LOCATION

TDD County: SAN JUAN

TDD State: CO

TDD: 1005-04

Date: 03/2012

URS OPERATING SERVICES

Sources:
USGS Topographic Map
Bing Maps

Created: 12/8/2010 3:26:46 PM Drawn By:andrew_longworth
File Location: T:\START3\Mogul and Grand Mogul\5.0 GIS\Maps\tech_memo\F1_SiteLocationMap.mxd

Legend

- Trench and Test Pit Locations
- Roads
- Surface Water
- Waste Piles

N

0 125 250 500 Feet

TDD Title: **Mogul and Grand Mogul**

Figure Title: Site Features

Figure No. 2

TDD State: CO

TDD County: DENVER

TDD: 1005-04

Date: 03/2012

Base Data Source: Bing Maps 2010, UOS GPS 2010

Datum/Projection: NAD 1983 Zone 13N UTM

Rev 0 07/2010

URS OPERATING SERVICES

Legend

- EPA Sample Locations - June 2010
- UOS - Field Parameter Points - June 2010
- Surface Water Sample Locations - June 2010
- Roads
- Surface Water
- Waste Piles

N

0 50 100 200 Feet

TDD Title: **Mogul and Grand Mogul**

Figure Title: Mogul Field Parameters

Figure No. 3

TDD State: CO

TDD County: DENVER

TDD: 1005-04

Date: 03/2012

Base Data Source: Bing Maps 2010, UOS GPS 2010

Datum/Projection: NAD 1983 Zone 13N UTM

Rev 0 07/2010

URS OPERATING SERVICES

Legend

- EPA Sample Locations - June 2010
- UOS - Field Parameter Points - June 2010
- Surface Water Sample Locations - June 2010
- Roads
- Surface Water
- Waste Piles

N

0 125 250 Feet

TDD Title: **Mogul and Grand Mogul**

Figure Title: Grand Mogul Field Parameters

Figure No. 4

TDD State: CO

TDD County: DENVER

TDD: 1005-04

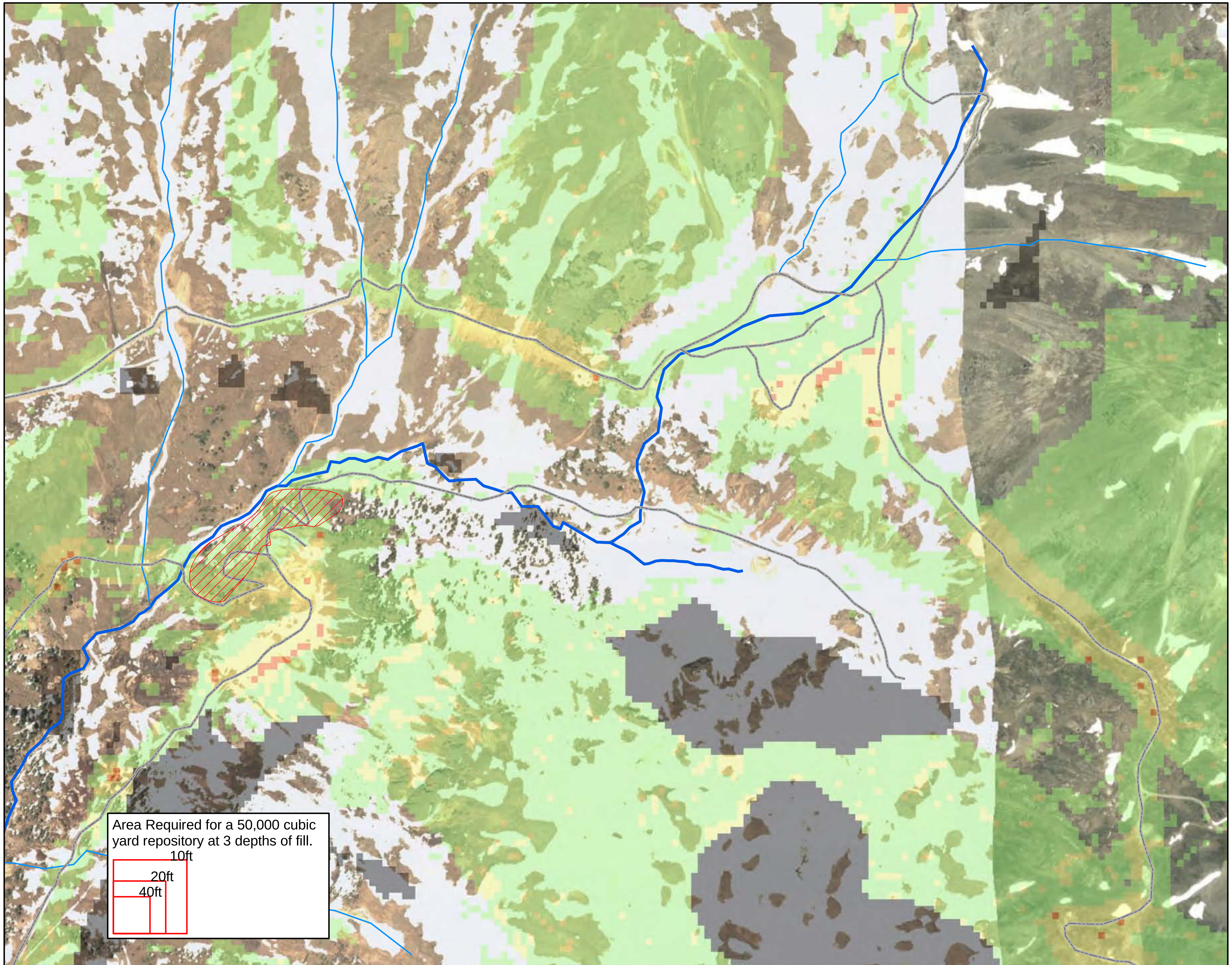
Date: 03/2012

Base Data Source: Bing Maps 2010, UOS GPS 2010

Datum/Projection: NAD 1983 Zone 13N UTM

Rev 0 07/2010

URS OPERATING SERVICES



Legend

Roads

Surface Water Channels

Primary

Secondary

Favorability

Unfavorable

Poor

Suitable

Good

Best

Potential Repository Location

N

0 200 400 800 Feet

TDD Title: **Mogul and Grand Mogul**

Figure Title: Potential Repository Location

Figure No. 5

TDD State: CO

TDD County: DENVER

TDD: 1005-04

Date: 03/2012

Base Data Source: NAIP 2008, UOS GPS acquisition 2010

Datum/Projection: NAD 1983 Zone 13N UTM

Rev 0 07/2010

URS OPERATING SERVICES

TABLE 1
Surface Water Sample Results
June 2010

Analyte	Sample ID Location	MMSW01 MM Waste Rock Seep Below Toe of Pile	MMSW02 MM Adit Flow Toe of Waste Pile	MMSW03 MM Adit flow Mid Waste Rock Pile	CC01F Basin Flow Above GM	CC01C Waste Seep From GM Pile 3	CC01H Basin Flow Below GM Piles 2 and 3	CC01S CC between GM Pile 1 and Pile 2	CC01T CC below GM Piles 2 and 3	CC02i Drainage Above CC GM Pile 1	CC02D MM Adit Flow at Flume	MTD-1 Waste Rock Seep Toe of MM Waste Pile	MTD-2 MM Adit flow at Toe of Waste Rock	MTD-3 MM Drainage Above CC	CCOPP-12 Approx 1 mile below MM and GM
Aluminum (µg/L)	Dissolved	4,400	2,200	2,000	<100	1,930	396	1,250	702	715	2,390	1,180	3,360	3,500	470
	Total	4,200	2,200	2,100	248	1,990	698	1,470	1,070	731	2,520	1,180	3,350	3,490	568
Arsenic (µg/L)	Dissolved	<0.42	<0.42	0.94J	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0
	Total	0.34J	1.9J	2.8J	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0
Beryllium (µg/L)	Dissolved	1.9J	3.1	2.9	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	3.5	<1.0	1.7	1.2	<1.0
	Total	1.6	3.1	3.2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	3.6	<1.0	1.6	1.1	<1.0
Cadmium (µg/L)	Dissolved	35	33	33	1.9	14.9	5.5	5.7	5.2	4.2	38.9	12.2	37.1	28.9	3.1
	Total	35	34	34	2.1	15.9	5.1	6.1	5.3	4.5	40.3	11.5	37.3	27.7	3.1
Calcium (µg/L)	Dissolved	58,000	140,000	140,000	18,100	11,800	16,900	25,000	20,700	22,100	168,000	27,100	74,000	43,500	13,000
Chromium (µg/L)	Dissolved	<1	<1	<1	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
	Total	1.5J	<0.5	<0.5	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Copper (µg/L)	Dissolved	590	43	26	27.2	295	141	57.5	88.4	33.7	22.3	87.9	529	491	56.9
	Total	600	47	26	44.2	292	140	61.5	95	35.8	22.6	85.1	533	485	57
Iron (µg/L)	Dissolved	4,900	8,800	15,000	<100	2,510	<100	<100	<100	144	22,000	395	8,830	4,320	<100
	Total	4,700	11,000	24,000	<100	2,700	752	<100	374	207	26,100	1,450	11,500	5,740	305
Lead (µg/L)	Dissolved	51	140	130	<1.0	36.5	3	2	2.9	2.6	153	31	87.2	45.4	3.1
	Total	50	140	140	11.5	40.2	11.7	3.5	8.3	3.6	168	40.6	98.2	50.6	5
Magnesium (µg/L)	Dissolved	5,200	8,200	8,300	1,740	2,140	1,890	3,720	2,720	2,940	10,200	2,160	5,880	3,800	1,440
Manganese (µg/L)	Dissolved	7,600	20,000	19,000	148	1,670	449	2,170	1,230	76.2	24,100	3,350	10,800	4,970	552
	Total	7,700B	18,000	20,000	157	1,730	455	2,270	1,310	80.1	25,400	3,550	11,400	5,290	585
Nickel (µg/L)	Dissolved	10	11	9.4J	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	8.8	4.3	7.3	7.5	<4.0
	Total	9.8	11	11	<4.0	4.7	<4.0	5.7	4.1	4.9	12.2	4.9	8.1	8.7	<4.0
Potassium (µg/L)	Dissolved	660J	1,400J	1,600J	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	1,840	<1,000	<1,000	<1,000	<1,000
Selenium (µg/L)	Dissolved	2.1J	<1.4	<4.9	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.4	<1.0	1	<1.0	<1.0
	Total	<0.7	<0.7	<0.7	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.6	<1.0	1.3	<1.0	<1.0
Silver (µg/L)	Dissolved	0.13J	<0.03	3.4J	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
	Total	0.26J	0.093J	0.036J	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

TABLE 1, cont.
Surface Water Sample Results
June 2010

Analyte	Sample ID / Location	MMSW01 MM Waste Rock Seep Below Toe of Pile	MMSW02 MM Adit Flow Toe of Waste Pile	MMSW03 MM Adit flow Mid Waste Rock Pile	CC01F Basin Flow Above GM	CC01C Waste Seep From GM Pile 3	CC01H Basin Flow Below GM Piles 2 and 3	CC01S CC between GM Pile 1 and Pile 2	CC01T CC below GM Piles 2 and 3	CC02i Drainage Above CC GM Pile 1	CC02D MM Adit Flow at Flume	MTD-1 Waste Rock Seep Toe of MM Waste Pile	MTD-2 MM Adit flow at Toe of Waste Rock	MTD-3 MM Drainage Above CC	CCOPP-12 Below MM and GM
Sodium (µg/L)	Dissolved	2,500B	4,600B	4,800B	830	569	988	932	1,060	1,140	5,430	1,870	3,000	2,120	622
Zinc (µg/L)	Dissolved	11,000	20,000	19,000	370	3,210	1,120	1,070	978	1,290	22,900	4,400	14,900	8,190	731
	Total	11,000	19,000	20,000	379	3,350	1,110	1,060	1,050	1,290	24,500	4,550	15,400	8,910	735
pH		3.82	2.67	4.5	5.72	3.45	5.53	5.13	5.27	3.92	3.58	3.6	3.02	3.15	5.07
Conductivity (mS/cm)		--	--	--	129	208	134	205	167	191	785	248	928	604	110
Flow (cfs)		0.02228	0.006684	0.02228	4.61	--	5.58	2.51	8.26	--	0.138	--	--	0.394	24.5

CC = Cement Creek GM = Grand Mogul Mine MM = Mogul Mine µg/L = Micrograms per liter ms/cm = MilliSiemens per centimeter cfs = Cubic feet per second B = The analyte was detected in the blank
J = The associated numerical value is an estimated quantity between the detection limit and the quantitation limit. -- = no sample data

TABLE 2
Waste Rock Samples

Sample ID	35B (AMLI Mine #35)		35C (AMLI Mine #35)		CC-SO-06	MMWR01	MMWR02
Sample Source	USGS 2007* Sample Obtained in 1997		USGS 2007* Sample Obtained in 1997		UOS START 2009^ Sample Obtained in 1996	START 2010	
Location Description	Grand Mogul Waste Rock Pile 3		Grand Mogul Waste Rock Pile 3		Mogul Mine Waste Rock Pile	Trench at Mogul Mine	Trench at Grand Mogul Mine Pile 3
Analysis / Analyte	ICP-AES (mg/kg)	SPLP (EPA Method 1312) (µg/L)	ICP-AES (mg/kg)	SPLP (EPA Method 1312) (µg/L)	ICP-AES (mg/kg)	ICP-AES (mg/kg)	ICP-AES (mg/kg)
Aluminum	48,000	1,800	42,000	2,000	850	--	--
Antimony	--	--	--	--	41	--	--
Arsenic	79	30	80	30	--	50	28
Barium	390	57	310	27	102	--	--
Beryllium	2	10	2	10	0.23 B	--	--
Cadmium	120	52	140	55	176	--	--
Calcium	1,700	1,300	1,600	1,300	127 B	--	--
Chromium	12	10	8	10	0.42 B	--	--
Cobalt	4	10	4	10	0.21 U	--	--
Copper	1,900	350	1,800	350	1,050	--	--
Iron	45,000	1,200	44,000	770	18,400	--	--
Lead	24,000	8,200		8,100	24,400	908	597
Magnesium	4,200	3,100	4,000	3,300	24.9 B	--	--
Manganese	3,000	2,400	2,600	2,600	373 J	--	--
Mercury	--	--	--	--	0.64 J	--	--

TABLE 2, cont.
Waste Rock Samples

Sample ID	35B (AMLI Mine #35)		35C (AMLI Mine #35)		CC-SO-06	MMWR01	MMWR02
Sample Source	USGS 2007 Sample Taken in 1997		USGS 2007 Sample Taken in 1997		UOS START 2009 Sample taken in 1996	START 2010	
Location Description	Grand Mogul Waste Rock Pile 3		Grand Mogul Waste Rock Pile 3		Mogul Mine Waste Rock Pile	Trench at Mogul Mine	Trench at Grand Mogul Mine Pile 3
Analysis / Analyte	ICP-AES (mg/kg)	SPLP (EPA Method 1312) (µg/L)	ICP-AES (mg/kg)	SPLP (EPA Method 1312) (µg/L)	ICP-AES (mg/kg)	ICP-AES (mg/kg)	ICP-AES (mg/kg)
Molybdenum	36	20	38	20	--	--	--
Nickel	6	10	6	10	0.21 U	--	--
Phosphorous	1,300	3,900	1,300	3,600	--	--	--
Potassium	22,000	1,800	19,000	1,700	631 B	--	--
Selenium	--	--	--	--	5	--	--
Silver	63	--	64	--	102	--	--
Sodium	1,700	370	1,400	170	216 B	--	--
Sulfate	--	81,300		79,900	--	--	--
Thallium	--	--	--	--	1.4 B	--	--
Tin	17	--	18		--	--	--
Titanium	900	50	800	50	--	--	--
Vanadium	77	10	75	10	2.2 B	--	--
Zinc	30,000	10,000	34,000	10,000	5800 J	279	565

mg/kg = Milligrams per kilogram µg/L = Micrograms per Liter B = The analyte was detected in the blank.
^ URS Operating Services, Inc. (UOS). 2009. "Data Gap Analysis – Revision 2 Upper Animas Mining District, Cement Creek" October, 2009.
* U.S. Geological Survey (USGS). 2007. Integrated Investigations of Environmental Effects of Historical Mining in the Animas River Watershed. San Juan County, Colorado Professional Paper 1651.

Table 3
Chemical Data Analysis - June, 2010

Sample ID	Location Type	Location Description	Dissolved Metals (µg/l)							Loading (lbs/day)			
			Copper	Zinc	Lead	Cadmium	pH	Conductivity (us/cm)	Flow Rate (cfs)	Copper	Zinc	Lead	Cadmium
CC01F	Cement Creek	Basin Flow above of GM	27.2	370	<1.0	1.9	5.72	129	4.61	0.68	9.20	--	0.05
CC01C	Feature	Waste Seep from Pile 3	295	3210	36.5	14.9	3.45	208	--	--	--	--	--
CC01H	Cement Creek	Basin Flow below GM Piles 2 and 3	141	1120	3	5.5	5.53	134	5.58	4.24	33.71	0.09	0.17
CC01S	Cement Creek	CC at GM between Pile 1 and Pile 2	57.5	1070	2	5.7	5.13	205	2.51	0.78	14.49	0.03	0.08
CC01T	Cement Creek	CC below GM Piles 2 and 3	88.4	978	2.9	5.2	5.27	167	8.26	3.94	43.58	0.13	0.23
CC02i	Feature	GM Pile 1 Drainage above CC	33.7	1290	2.6	4.2	3.92	191	*0.016*	*0.003*	*0.11*	*0.0002*	*0.0004*
CC02D	Feature	MM Adit Flow at flume	22.3	22900	153	38.9	3.58	785	0.138	0.02	17.05	0.11	0.03
MMSW03	Feature	MM Adit flow - Mid Waste rock pile	26	19000	15000	33	4.5	814	0.02	0.00	2.05	1.62	0.00
MMSW02	Feature	MM Adit Flow - Toe of Waste Pile	43	20000	8800	33	2.67	820	0.007	0.00	0.76	0.33	0.00
MTD-2	Feature	MM Adit flow at Toe of Waste Rock	529	14900	87.2	37.1	3.02	928	--	--	--	--	--
MTD-1	Feature	Waste Rock Seep Toe of MM Waste Pile	87.9	4400	31	12.2	3.6	248	--	--	--	--	--
MMSW01	Feature	MM Adit and Seep, Toe of MM Waste	590	11000	4900	35	3.82	814	0.02	0.06	1.19	0.53	0.00
MTD-3	Feature	MM drainage above CC	491	8190	45.4	28.9	3.15	604	0.394	1.04	17.41	0.10	0.06
CCOPP-12	Cement Creek	Below M and GM	56.9	731	3.1	3.1	5.07	110	24.5	7.52	96.61	0.41	0.41

QAT = Queen Anne Tributary GM = Grand Mogul Mine MM = Mogul Mine CC = Cement Creek µg/L = Micrograms per liter ms/cm (milliSiemens per centimeter) CFS = Cubic Feet per Second
lbs/day = pounds per day Shaded Sample ID = EPA sample location Italics = Estimated based on flow from previous sampling events.

APPENDIX A

Photo Documentation

Photo 1: Mogul Mine Overview.

Photo 2: Mogul Mine adit discharge routed to the south side of the waste rock pile. Note plastic lined channel.

Photo 3: Mogul Mine Lower Tier

Photo 4: Mogul Pile Lower Tier. Note bedrock Outcrop just below People

Photo 5: Mogul Pile Lower Bench. Water emitting from Lower Tier.

Photo 6: Mogul Lower Tier view east.

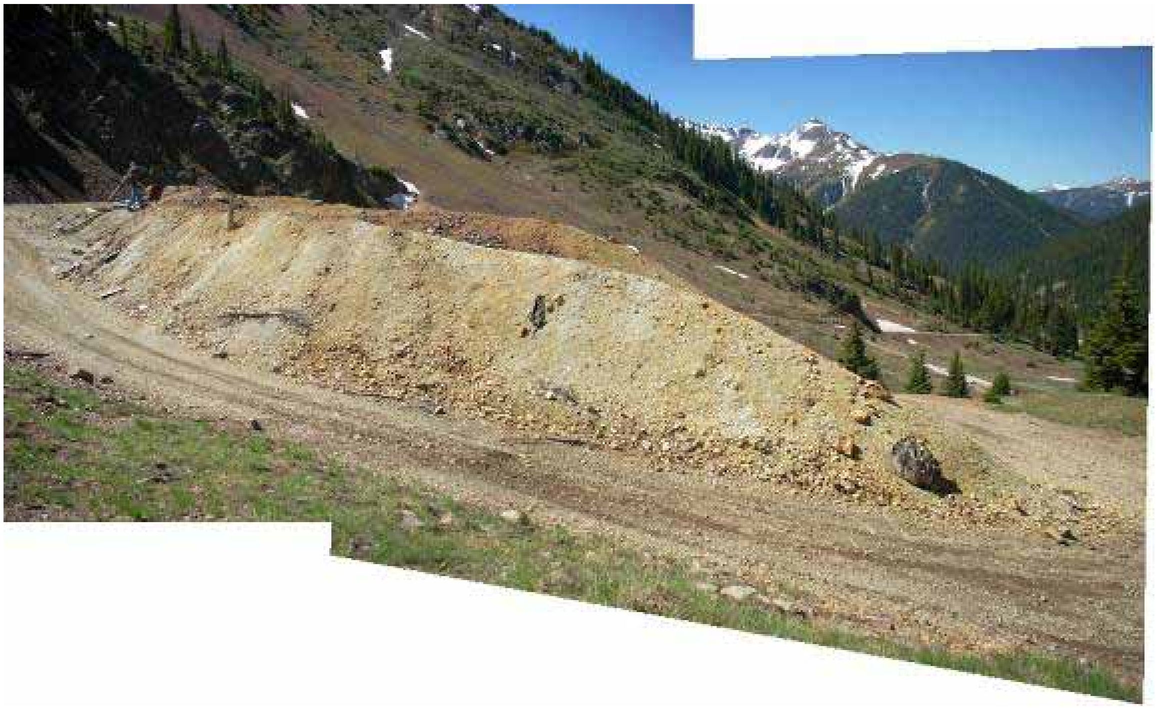


Photo 7: Mogul Upper Tier, view south.

Photo 8: View of down valley from top of Mogul Mine piles

Photo 9: Mogul Mine Upper Tier looking east from access road.

Photo 10: Mogul Mine Upper Tier.

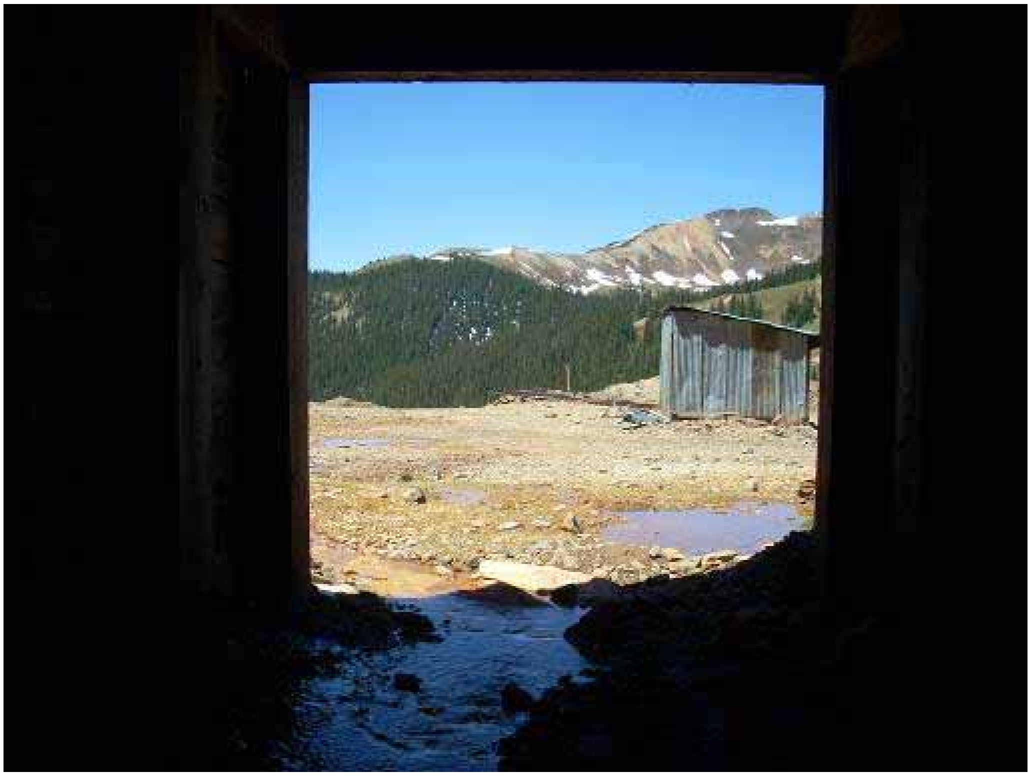


Photo 11: Inside Mogul adit.

Photo 12: Down valley at potential repository site

Photo 13: Up gradient/ up valley of potential repository

Photo 14: MMSW01. Below Mogul Mine dump

Photo 15: MMSW02. Below Mogul Toe

Photo 16: MMSW03. South side of tailings.

Photo 17: Unnamed Adit and Gold Hill Mine from Mogul Mine piles top

Photo 18: Unnamed Adit bulkhead and drain. This adit is 500 feet south of the Mogul Mine

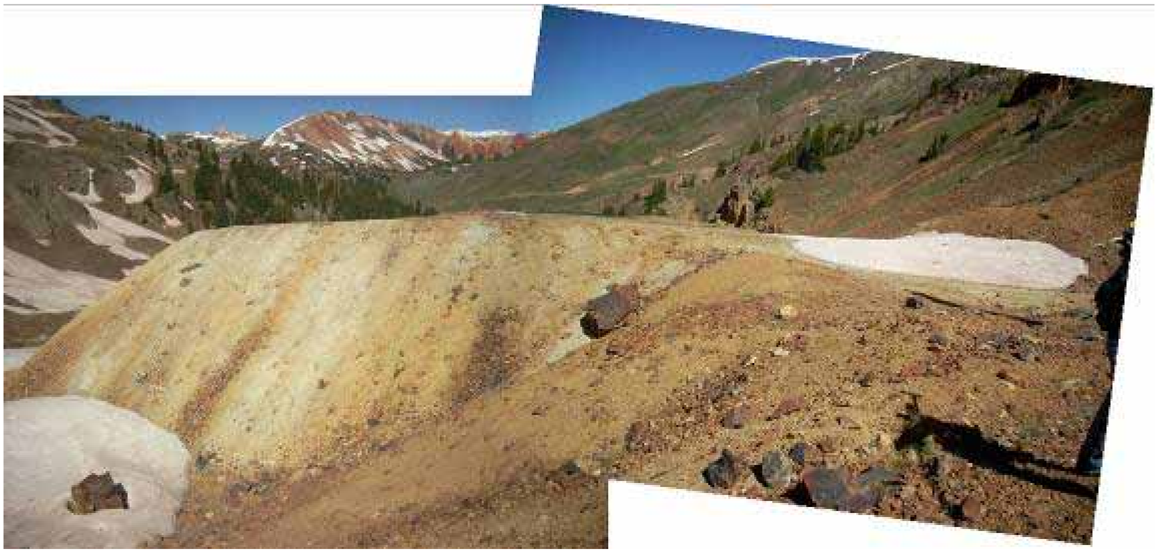


Photo 19: Grand Mogul Pile 3. View west, down valley.


Photo 20: Down valley from the top of Grand Mogul Pile 3.

Photo 21: Top of Grand Mogul Pile 3.

Photo 22: Seep and flow coming from Upper Grand Mogul Pile 3

Photo 23: Up-valley view of the Grand Mogul Pile 2 (Left central picture) and Pile 3 (distant, central picture).

Photo 24: Down-valley view of the Grand Mogul Mine Site. Pile 3 is in the right-foreground, Pile 2 is in the right-central portion.


Photo 25: Grand Mogul Mine Waste Pile 1


Photo 26: Trench at Mogul Mine facing east, mine portal visible in top of picture

Photo 27: Trench at Mogul Mine facing west. Water pooling in lower third of picture is arising from a seep along the edge of the trench closest to the mine portal.

Photo 28: Trench at Mogul Mine Facing East. Water is seeping into trench from eastern end from about 3 feet below ground surface.


Photo 29: Mogul Mine Trench facing east following reinstatement of excavated materials


Photo 30: Mogul Mine Trench 2.

Photo 31: Mogul Mine Trench 2 following reinstatement of excavated materials, Mogul Trench 3 and Grand Mogul Trench 1 were restored to the same condition.

Photo 32: Mogul Mine Trench 3.

Photo 33: Grand Mogul Trench 1

Photo 34: Grand Mogul Trench 2 following reinstatement of excavated materials.

Photo 35: Grand Mogul Trench 2 extending west, no seeps were visible in this reach.

Photo 36: Grand Mogul Trench 2 looking South.

Photo 37: View of Trench 2, discharge is in the fore of the picture talus rock is evident above.